REMARKS/ARGUMENTS

Reconsideration is respectfully requested.

Applicants respectfully acknowledge the Examiner's indication that the claim amendments have overcome the rejections over U.S. Patent No. 6,147,727 (Shigeno) and U.S. Patent No. 6,266,116 (Ohta) in view of U.S. Patent No. 5,598,285 (Kondo).

Applicants, however, respectfully comment that the **provisional application** of U.S. Patent No. 6,341,001 (Kwok) noted by the Examiner should be considered a properly qualified prior art reference under 35 U.S.C. §103 as asserted in the Office Action only if the **enabling disclosure** of the features of Kwok, the patent reference, cited by the Examiner to reject the claims of the present application is provided in the provisional application itself. It is respectfully noted that the Office Action cites Kwok, the patent reference, not the provisional application of Kwok. Thus, Applicants respectfully request a specific showing of enabling disclosure in the provisional application itself for each of the cited features of Kwok that was used to reject the claims of the present application. Otherwise, it is respectfully requested that Kwok, the patent reference, be removed from being a valid prior art reference. A certified translation of the Korean patent 1999-25214 is also submitted herewith.

While respectfully asserting that Kwok, the patent reference, should not be considered a properly qualified reference for the above reasons, the amended and new claims of the present application (as discussed in detail in the Remarks below) are nevertheless considered to have been distinguished from Kwok, the patent reference.

Claims 1-2, 5-7, and 9-10 stand rejected under 35 U.S.C. §103(a) as being unpatentable over <u>Kwok</u> in view of U.S. Patent No. 6,323,927 (Hiroshi) and further in view of U.S. Patent No. 3,837,729 (<u>Harsch</u>).

The presently claimed invention is directed to "a reflective type <u>**fringe field**</u> <u>switching mode</u> liquid crystal display" (or "a reflective FFS-LCD") as recited in the preamble of each claim. The fringe field switching (FFS) mode technology (which has been pioneered by Hyundai Display, predecessor in interest of the present assignee of this application) **simultaneously** provides the results of both the high transmittance and the wide viewing angle, while keeping the liquid crystal director to rotate in-plane as in the conventional in-plane switching (IPS) mode. The details of the FFS mode technology, in general, is described in the article, "<u>A High Quality Fringe-Field Switching Display for Transmissive and Reflective Types</u>" Journal of Information Display, Vol. 1, No. 1, December 2000, authored by Seung Hee LEE, Seung Ho HONG, Yeon Hak JEONG, and Hyang Yul KIM. The authors LEE and HONG of the "article" are also the joint inventors/Applicants of the present application having the U.S. filing date of June 29, 2000 and the priority date of June 29, 1999 (Korea). This "article" is submitted for the sole purpose of providing background, albeit not prior art, to support the benefits of the claimed FFS mode technology."

The FFS mode technology provides numerous advantageous characteristics such as minimized crosstalk, improved viewing angle and color shift, and faster response time as they are well described in page 12 of the "article." These advantageous characteristics are achieved by the structure of the electrodes arranged in a predetermined manner to form the fringe field in

the liquid crystal layer.

Such requisite structure of the electrodes necessary to create the fringe field in the liquid crystal layer is well described in the Specification page 9, lines 8-23 of the present application:

> "To form a fringe field, it is desirable that **interval** between the strip 46b of the pixel **electrode 46** and the branch 43b of the **counter electrode 43** is **narrower** than that of the **cell gap d11** .... In addition, the ratio of the width P12 of the strip 46a of the pixel electrode 46 to the width P11 of the branch 43a of the counter electrode 43 is 0.2 to 4 or so."

These structural parameters of the counter and pixel electrodes are necessary in order that the "liquid crystal molecules in the upper of the electrodes 43a, 46a are sufficiently driven by the fringe field between the electrodes 43a, 46a" (the Specification, page 9, lines 24-27). These structural parameters of the FFS mode are also consistent with the structural parameters disclosed in page 10 of the "article."

In case of an IPS mode and due to the IPS mode characteristics, it is generally difficult to fabricate a cell because $d^*(\Delta n(\lambda))$ of LCD in use is of a low value in the absence of a voltage being applied. In the FFS mode, however, fabricating a cell becomes much easier, because $d^*(\Delta n(\lambda))$ of LCD in use is higher than that of the IPS mode.

Further, <u>Kwok</u> discloses that the retardation in the liquid crystal layer having a phase difference occurs in accordance with the twist angle. This is a characteristic feature of a TN mode liquid crystal layer as shown in the drawings of <u>Kwok</u>. In contradistinction, the presently claimed invention relating to the FFS-mode LCD does not depend on the twist angle due to the structure of the FFS mode LCD.

It is respectfully submitted that <u>Kwok</u>, the patent reference (even if it were to be

construed as a properly qualified prior art reference), however, does not teach or suggest any of the above necessary structural parameters of the FFS-mode technology required to generate the fringe field in the liquid crystal layer, and the claims thus distinguish Kwok.

Hiroshi explicitly discloses that it is directed to IPS mode LCD without any teaching or reference to the FFS mode of the presently claimed invention. As illustrated at page 10 of the "article," the IPS mode is substantially different from the FFS mode and utilizes a very different electrode structure, among others.

Harsch also fails to disclose the FFS mode as the electrodes (such as 18 and 20 of FIG. 1 of Harsch) are not arranged to be planar on one side of the liquid crystal layer. Instead, the electrodes of Harsch are separated by the liquid crystal layer and disposed on each of the two sides of the liquid crystal layer (see FIG. 1 of Harsch). This is shown in Harsch as a typical conventional twisted nematic LCD structure of the early days of LCD development and is thus quite different from the presently claimed invention directed to the FFS mode for generating the fringe field.

In view of the above, the independent Claims 1 and 7 have been amended to recite that --the counter electrode and the pixel electrode are separated by a predetermined distance that is less than the cell gap thickness to generate a fringe field to drive the liquid crystal molecules--. As none of the cited references (individually or in combination) teach or suggest or even relate to the FFS mode LCD and the structure that is necessary to create the fringe field, Claims 1 and 7 as amended and the new Claims 11-12 are not taught or suggested by the cited references. This is true even if Kwok, the patent reference, were to be applied.

For the reasons set forth above, the Applicants respectfully submit that the Claims 1-2 and 4-12, now pending in this application, are in condition for allowance over the art of record. This Amendment is considered to be responsive to all points raised in the Office Action. Accordingly, Applicants respectfully request reconsideration and withdrawal of the outstanding rejections and earnestly solicit an indication of allowable subject matter. Should the Examiner have any remaining questions or concerns, the Examiner is encouraged to contact the undersigned attorney by telephone to expeditiously resolve such concerns.

Respectfully submitted,

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Vangeli Economou

Vangelis Economou, Reg. No. 32,341
c/o Ladas & Parry
224 South Michigan Avenue
Chicago, Illinois 60604
(312) 427-1300

Attachments:
(1) Verification of Translation of the Application
(2) "A High Quality Fringe Field Switching Display for Transmissive and Reflective Types" Journal of Information Display, Vol. 1, No. 1, December 2000, authored by Seung Hee LEE, Seung Ho HONG, Yeon Hak JEONG, and Hyang Yul KIM

A High Quality Fringe-Field Switching Display for Transmissive and Reflective Types

Seung Hee Lee, *Member*, Seung Ho Hong, *Member*, Yeon Hak Jeong and Hyang Yul Kim

Abstract

In liquid crystal displays, the display mode that represents initial liquid crystal alignment and method of applying voltage, mainly determines the image quality of display. Recently we have developed the fringe-field switching (FFS) mode exhibiting high image quality. In this paper, a pixel concept, manufacturing process, materials, and electro-optic characteristics of the FFS mode comparing with conventional in-plane switching mode, and its possible application to reflective type are discussed.

Keywords : Liquid crystal display (LCD), fringe-field switching (FFS), transmissive and reflective display

1. Introduction

FRINGE FIELD SWITCHING

Recently, the market of liquid crystal display (LCD) is growing fast in liquid crystal TV as well as in monitors. In order to accelerate the replacement of CRT to LCD in monitor as well as TV field, lowering cost and improving image quality are necessary. Pursuing a high quality active matrix LCD (AMLCD), we have developed new wide-viewing-angle technology, [redacted] (FFS)[1-5], showing unique electro-optic characteristics while keeping the liquid crystal (LC) director to rotate in-plane as in the conventional IPS mode [6]. We have already manufactured 15.0" and 18.1" TFT-LCDs for transmissive type and 15.0" for reflective type utilizing the FFS mode. The module shows wide-viewing angle, high transmittance, low crosstalk, and relatively fast response time in grey scales. The reflective display also shows wide viewing angle owing to in-plane orientation. The FFS mode is also becoming popular such that the results about the FFS device from others are being reported. In this paper, the overall characteristics of the FFS mode and possible application to reflective LCD are reviewed.

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S. H. Lee, S. H. Hong, Y. H. Jeong and H. Y. Kim are with the TFT Process Development Department, LCD SBU, Hyundai Electronics, SAN 136-1, Ami-ri, Bubal-eub, Ichonsi, Kyungki-do 467-701, Korea. E-mail : lshl@hei.co.kr Tel : +31 639-6452 Fax : +31 639-6458

2. Characteristics of the FFS Mode

2.1 One pixel concept in array and cell structure

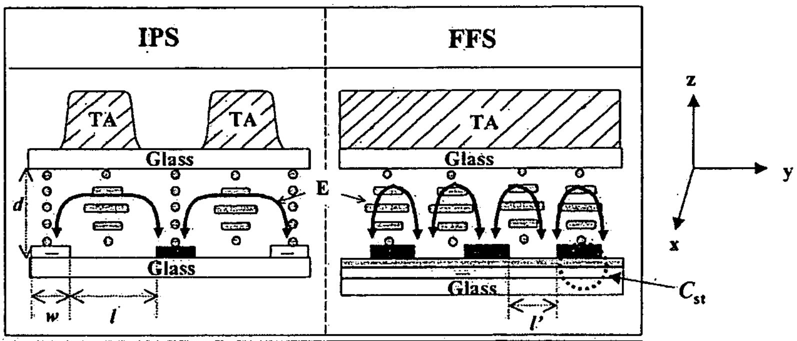
Considering one pixel of the FFS mode is an interesting concept. In the conventional IPS mode, the distance (l) between pixel and common electrodes is larger than that of the cell gap (d) and the width of pixel electrodes (w), resulting in horizontal field (E_y) with bias voltage. In this case, the storage capacitance (C_{st}) exists in non-active area, that is, the higher C_s, the lower the transmittance. However, the concept of interdigital electrodes in the FFS mode is discarded. Instead, there is no horizontal distance between pixel and common electrodes with passivation layer between them while the distance (l') between pixel electrodes exists with a ratio of electrode width to distance about 0.5~2. In this case, with bias voltage, the fringe field lines with vertical (E_z) and horizontal components are generated, as shown in Fig.1. Further, in the FFS mode, the C_{st} exists automatically in an active area without losing the aperture ratio. Also, it is much larger than that of the IPS mode. In the cell structure, the liquid crystal molecules are homogeneously aligned with optic axis coincident

with one of the transmission axis of the crossed polarizers in the off state so that it appears black. With bias voltage, the fringe-field drives the LC director to rotate above whole electrodes, causing much higher transmitted area (TA) than the IPS mode as shown in [redacted]

FIG. 1

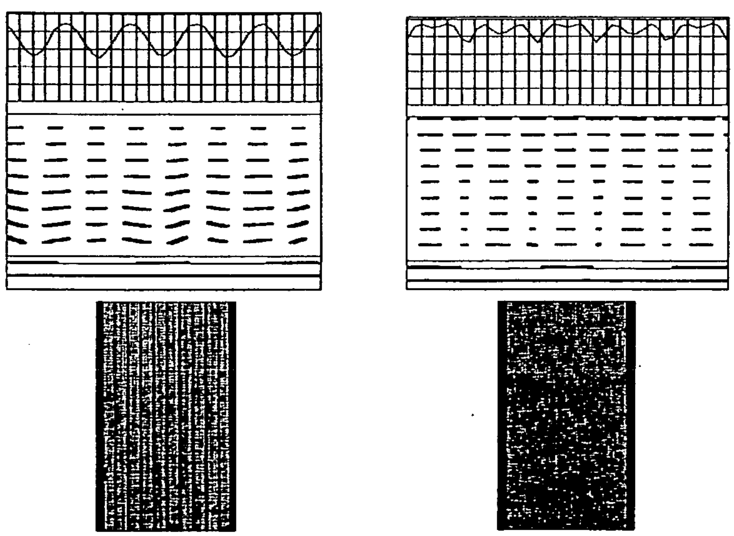
2.2 Process

In the array process of the FFS mode, two ITO layers are necessary since LC director modulates light even above electrodes which is the only demerit of the FFS mode, even though the ITO is not necessary for color



	IPS	FFS
l/d	>1	<1 or 0
l/w	>1	<1 or 0
Field	Ey	Ey, Ez
Electrodes	Metals or ITO	ITO

Fig. 1. Comparison of the IPS and the FFS modes indicating the differences in electrode structure and light transmitted area.



(a) (b)

positive LCD

Fig. 2. The simulational results and real pictures of one pixel for (a) the positive LC and (b) the negative LC.

filter side. Conventional twisted nematic (TN) mode needs ITO layers on top and bottom substrates, so the resulting number of ITO layers between TN and FFS modes are the same. In the IPS mode, the thickness of electrodes in light modulated area is at least above 1000 Å since they are composed of opaque metals for gate and data bus lines. Consequently, a perfect alignment of the LC director near the electrodes is difficult unless the array substrate is planarized. However, in the FFS mode, the thickness of ITOs is only few hundred Å. So, good alignment of liquid crystal molecules with homogeneous alignment layers can be obtained without the planarization of the array substrate.

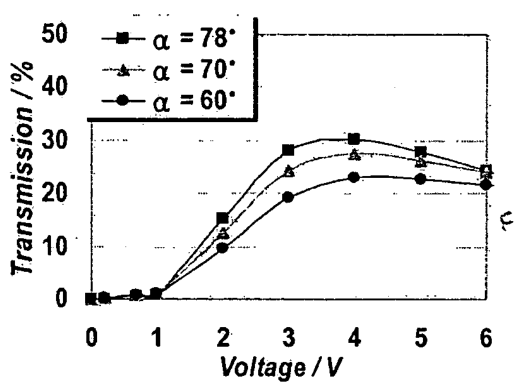


Fig. 3. The simulation results of voltage-dependent transmittance curves depending on rubbing angle(α).

TABLE Comparison of voltages at different greys for the cells with resin and Cr BM.

BM	V_{10}	V_{50}	V_{90}
Resin	2.21	3.30	4.88
Cr	2.21	3.31	4.90

2.3 Materials

2.3.1 color filter

In the IPS mode, the resin black matrix (BM), that is, a high specific resistance material, is required to block field disturbance caused by conductive chromium (Cr) BM. In the IPS mode, the cell gap is shorter than the distance between electrodes so that the field strength between common line and BM is stronger than that between electrodes. Consequently Cr BM disturbs in-plane field between electrodes, causing to increase operating voltage [7]. However, in the FFS mode there is no horizontal distance between pixel and common electrodes, that is, the field strength caused by Cr BM of upper substrate does not affect the field distribution in light modulated area.[8] We have checked the voltages at which the transmittance changes by 10%, 50%, and 90% for both cases and the results are almost the same as shown in table. When the Cr BM is used, the depth difference on overlapped area between color resin and BM and the LC modulated area is minimized. This allows for good alignment of LC molecules. This is another advantage of the FFS mode.

2.3.2 liquid crystal

In the FFS mode, both positive and negative dielectric anisotropy of the LC can be used. When the positive LC is used, the LC director tilts up along the fringe field line instead of rotation so that the degree of twist above center of electrodes is low, resulting in low transmittance. However, when the negative LC is used, the rotation of LC director occurs in the whole area, resulting in high transmittance. These phenomena are well illustrated in FIG 2 [redacted]For a cell with the positive LC, the light transmission oscillates like a sine function and is low above the center of electrodes. The photo of one pixel below simulational result also exhibits dark and bright striped lines along horizontal axis but such lines are not observed in a cell with negative LC. However, adjusting the phase retardation of the cell, physical properties of the LC, and electrode design can reduce the difference in light efficiency. With an optimized condition, it could be over 90% of that of the negative one. In the IPS mode, the light efficiency for both types of LCs is the same. Another distinct difference between the IPS and the FFS modes is voltage-dependent transmittance curves depending on rubbing directions.[redacted]hows that the FIG 3 transmittance decreases with decreasing rubbing angle (α) with respect to horizontal component of fringe field for the positive LC case, whereas it remains the same for negative LC one. Since the dielectric torque and the elastic force between neighboring molecules rotate the LC director in the FFS mode, the less elastic force caused by tilt-up molecules near the edge of the electrodes causes less twist deformation above the electrodes as the rubbing direction decreases for the positive LC. This result is very important in obtaining a FFS device with fast response time and high light efficiency because the rotational viscosity of the positive LC is less than that of the negative one at the present level.

3. Electro-optic Characteristics of the FFS Mode

3.1 Crosstalk

Another distinct characteristic of the FFS mode is crosstalklessness. The crosstalk is inversely proportional to total capacitance but is proportional to coupling capacitance between pixel and data bus line electrodes and fluctuation of pixel electrode potential in the case of dot inversion. As mentioned above, since the number of pixel electrodes in one pixel is more than 5, the C_{st} is much larger than that of the IPS mode. As a result, the fluctuation of a pixel potential is suppressed, so the crosstalk is less than 1%.

3.2 Viewing angle and color shift

Basically, the LC director in the FFS rotates in plane like the IPS cell except that the degree of twist alternates in the FFS mode. Such effect improves uniformity in brightness and results in less yellowish and bluish color change than that of the IPS cell. The contrast ratio greater than 10 exists over 80° in all directions.

3.3 Response time

In the FFS mode, the response time of the device depends on the design of pixel electrodes, the cell gap, viscosity and elastic constants of the LC. At the present level, the rotational viscosity of the negative LC is intrinsically higher than that of the positive one. Therefore, the rising and decaying response times of the FFS device with 90% change of light transmittance are 22ms and 28ms, respectively. However, with the use of the positive LC while manufacturing the same cell gap, the response time obtained was 32ms. Further, we will present the FFS device with 25ms in another publication.

4. Application of the FFS Mode to Reflective LCD (R-FFS)

The concept of in-plane orientation of LC director can be applied to a reflective LCD, owing to high transmittance characteristic of the FFS mode. Several types of the cell structures with one or two polarizers and with or without compensation films are possible. Fig. 4 shows a principle of operation for normally black mode with one polarizer (P) and $\lambda/4$ plate. In the off- state, the optic axes of the LC director and the P are coincident while having 45° between the P and the slow axis of $\lambda/4$ plate. Therefore, the polarization state of incident light passed quarter plate becomes circular and when reflected, the light with circularly polarization becomes linearly polarized after passing the retardation film. However, this linearly polarized light is 90° rotated so the polarizer blocks the light. For the bright state of the cell with a half-wave retardation, the optic axis of the half-wave LC layer is rotated by 22.5° by applying appropriate voltage to the cell. Then, the linearly polarized input light is rotated by 45° passing through the LC layer. At this point, the polarization is in parallel with the optic axis of the quarter-wave retardation film. Therefore, the light maintains polarization during the double pass through the quarter-wave film. And then, the reflected light is rotated by -45° by propagating through the LC layer once more. Finally, the reflected light is linearly polarized again, which is in parallel with the transmission axis of the polarizer. So, the bright state is achieved. Fig. 5 shows the simulational results of the device exhibiting viewing angle characteristics in horizontal and vertical directions based on Berreman's 4X4 method. The results show no grey scale inversion up to 60° of polar angle. Fig. 6 shows the voltage-dependent reflectivity curve, where the light source is located at a polar angle of −30° and is detected at a polar angle of 10°. The voltage showing maximum transmittance is only 3.5*V*. In conclusion, the R-FFS mode shows intrinsically no grey scale inversion over wide range owing to in-plane rotation, and also, low driving voltage since LC director rotates only by 22.5°.

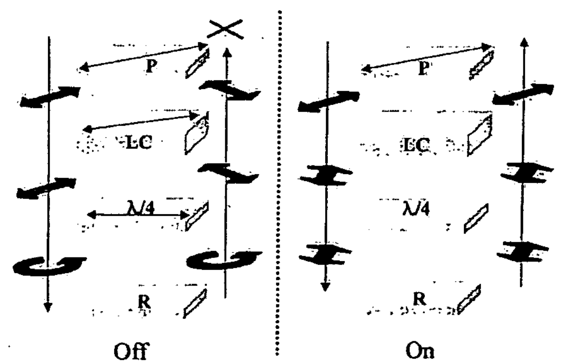
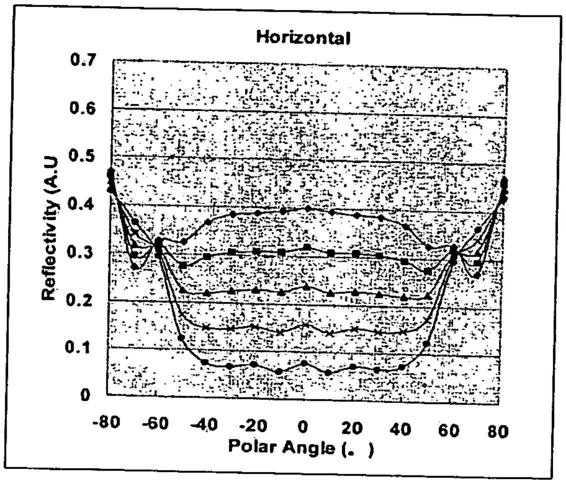
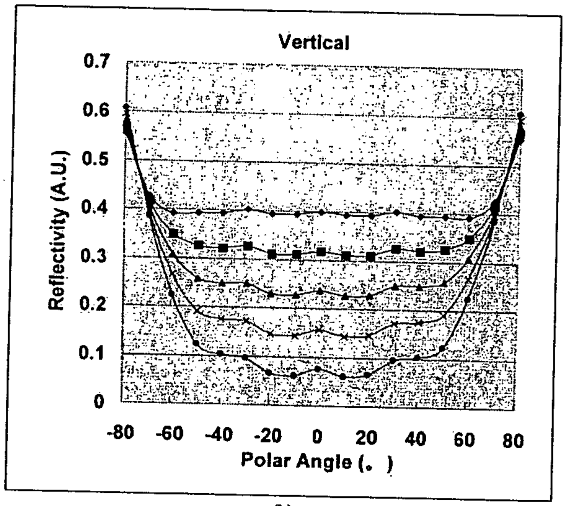


Fig. 4. Cell structures of normaly black reflective system with one polarizer and quarter wave film with state of polarization in each pass.



(a)



(b)

Fig. 5. The simulated results of the viewing angle characteristics using the one polarizer with quarter wave plate.

5. Summary

The FFS display, which has a concept of new pixel electrode discarding conventional interdigital electrode used in conventional IPS display, exhibits high transmittance, wide-viewing-angle, and low crosstalk. In this paper, the overall characteristics of the FFS mode are reviewed. Also, an application of the FFS mode to reflective system is possible, and reflective FFS mode shows wide viewing angle and low driving voltage for one polarizer system with quarter wave film.

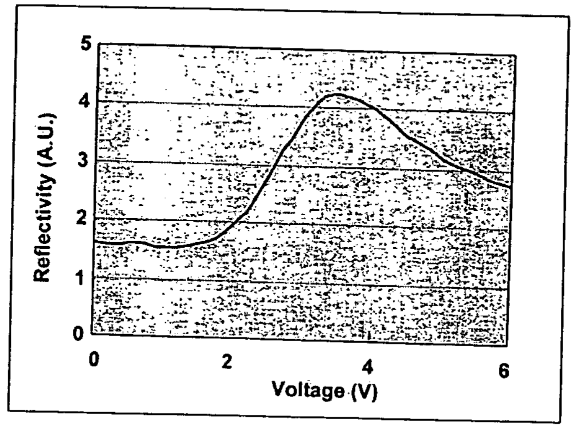


Fig. 6. The voltage dependent reflectivity curve of the reflective device.

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